Whole-farm modelling using different grazing-management strategies with diverse pastures within an irrigated dairy-farm system

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Abstract

The objective of this study was to assess the effect of diverse pasture mixtures and grazing management on profitability of Canterbury dairy farms using a commercial modelling tool, Farmax Dairy Pro. Two years of pasture growth and quality data were obtained from irrigated plots sown with a pasture mixture consisting of perennial ryegrass, white clover, red clover, chicory and plantain (diverse) or the same pasture mixture plus Italian ryegrass (diverse-Italian). Pastures were subjected to one of three grazing management regimes: (1) conventional grazing (grazed to a compressed height of 3.5 cm all year); (2) spring lenient grazing; and (3) autumn lenient grazing. The data were fitted to a base model farm (average of North Canterbury region) using Farmax Dairy Pro to produce six different farm scenarios. Farm scenarios were ranked and compared by profit expressed as earnings before tax. Pastures managed by autumn lenient grazing resulted in the lowest DM production, more supplement purchased, and hence, lowest profit compared with conventional or spring lenient grazing management. The diverse pasture managed by spring lenient grazing resulted in the greatest profit ($2,658/ha) compared with other scenarios (average $2,261/ha). This greater profit was driven by greater annual DM production per hectare and, hence, less supplement purchased. When diverse pasture is considered, spring lenient grazing is a potential management option for irrigated Canterbury dairy farm systems to increase DM production and thereby profitability.

Keywords: diverse pastures; FARMAX; pasture growth; DM production

Introduction

Dairy farming in New Zealand is primarily based on grazed pastures comprising of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) mixtures. However, such a sward mix is subjected to seasonal variations in growth rate and nutrient composition, causing herbage to be insufficient to meet the animal requirements during some periods (Burke et al. 2002). In comparison to the ryegrass-white clover mixture, a diverse mix sward that includes legumes and herbs has been reported to provide a more-even distribution of dry matter production and feed quality throughout the grazing season (Nobilly et al. 2013; Sanderson et al. 2007). In addition to the sward mixture, grazing management such as lenient grazing (pasture grazed to compressed height of 5-6 cm) could be used as a strategy to produce more DM per ha (Da Silva et al. 1994; Matthew et al. 2000). There is limited data available on grazing management of diverse mixed swards, resulting in low adoption by producers.

Grazing management strategies are designed to ensure a year-round balance of forage supply and demand to reduce the effect of seasonal and annual variability in weather. However, quantifying the usefulness of given strategies in a farming system and for multiple seasons is risky and expensive. Computer models are increasingly being used to simulate farming systems. Results of simulations are used to complement experimental studies and help to understand the implications of various management options in different environmental conditions (Snow et al. 2014). Farmax Dairy Pro is a simulation model which predicts the effects of farming system changes on production and financial performance (Bryant et al. 2010). It enables feed supply and demand to be estimated in a farm system. However, there has been little evaluation of diverse pasture mixtures that includes herbs and alternative legumes managed by tactical defoliation strategies.

We identified pasture growth rates based on different grazing management strategies and pasture-mixture types. However, the effect of these pasture mixes and grazing managements on farming-system profitability is still unclear. Therefore, the objective of this study was to use a commercial modelling tool, Farmax Dairy Pro, to assess the effect of diverse pasture mixtures and grazing management on profitability of Canterbury dairy farms.

Materials and methods

Data collection and measurements

Two years of pasture growth and quality data were obtained from irrigated plots sown with a pasture mixture. The pasture mixture consisted of perennial ryegrass, white clover, red clover, chicory and plantain (diverse) or the same pasture mixture plus Italian ryegrass (diverse + Italian) in a 2 x 3 randomised block design, with two pasture types and three grazing management replicated three times. Grazing management regimes were (1) conventional grazing, where cows grazed to a compressed pasture height of 3.5 cm year-round, (2) autumn lenient grazing, where cows grazed to a compressed pasture height of 5 cm during autumn before a switch to 3.5 cm for the remainder of the year and (3) spring lenient grazing, where cows grazed to a compressed pasture height of 5 cm during spring before a switch to 3.5 cm for the remainder of the year. All plots were subjected to a rotational grazing, scheduled to occur when average compressed height of pasture across all treatments reached 9-10 cm on the rising plate meter (RPM). For the spring lenient grazing management, grazing occurred when perennial ryegrass reached seed head (anthesis) development in spring. Pasture growth rate (kg DM/ha/d) was calculated from the difference between pre-grazing herbage mass from the current grazing event and post-grazing herbage mass from the previous grazing event, divided by the number of days between pre-grazing herbage mass and post-grazing herbage mass. Pre- and post-grazing herbage mass was measured directly using quadrat cuts ($0.2m^2$). Pre- and post-grazing herbage samples (n = 2043) were cut to the ground level and oven dried at 60°C for 48 h for determination of DM production. The herbage samples were then ground through 1-mm sieve using a ZM200 rotor mill (Retsch Inc., Newtown, Pennsylvania, USA). The herbage digestible organic matter (DOM) content was determined using near infrared spectroscopy (NIRS; Foss Feed and Forage Analyser 5000, Maryland, USA). Metabolisable energy (ME) of pre- and post-grazing herbage samples was estimated based on the equation ME (MJ/kg DM) = 0.16 x DOM (% in DM). The ME of the diet was estimated based on the equation ME (MJ/kg DM) = $[(ME_{\text{pre-grazing herbage}}$ *pre-grazing herbage mass) – $(ME_{\text{post-grazing herbage}}$*post-grazing herbage mass)]/ (pre-grazing herbage mass – post-grazing herbage mass) (Dalley et al. 1999).

Modelling scenarios

The pasture growth (kg DM/ ha/d) and quality (ME of diet MJ/kg DM) data were then fitted to a base farm model using Farmax Dairy Pro. (Version 6.6.5.0, FARMAX, Waikato Innovation Park, Hamilton, New Zealand), resulting in six different farm scenarios:

(1) diverse pasture + conventional grazing (DP + CG),
(2) diverse pasture + autumn lenient grazing (DP + AL),
(3) diverse pasture + spring lenient grazing (DP + SL),
(4) diverse pasture + Italian ryegrass + conventional grazing (IDP + CG),
(5) diverse pasture + Italian ryegrass + autumn lenient grazing (IDP + AL),
(6) diverse pasture + Italian ryegrass + spring lenient grazing (IDP + SL).

Base model and management assumptions

The base farm model was a representative of the average farm systems in the North Canterbury region with an effective area of 229 ha (LIC 2015), irrigated by a centre pivot. Physical assumptions used for this model included dairy breed, Holstein-Friesian × Jersey crossbred cows of mixed age, stocking rate of 3.4 cows/ha, milksolids (MS) production per cow of 416 kg MS/cow/year and nitrogen fertiliser application rate of 150 kg N/ha/year. Replacement stock were reared off farm and wintering cows (non-lactating cows during the winter period) were moved off the milking platform from late May and returned just before calving. Planned start of calving date was 1 August, with cows achieving peak milk production in spring, mid-October.

Table 1 Physical assumptions used in simulation modelling for dairy cows grazing one of two pasture mixtures (diverse pasture or diverse pasture + Italian ryegrass) and were subjected to one of three grazing management (conventional, lenient in spring or lenient in autumn)

Grazing area	229	ha
Stocking rate	3.4	cows/ha
Milksolids per cow	416	kg/cow
Nitrogen fertiliser	150	kg N/ha
Cow numbers 1st June	796	cows
Days in milk	261	days
Average body condition score at calving	4.8	BCS

The dry-off date was in autumn (May 28) resulting in an average lactation length of 261 days for the herd. All farm scenarios were subjected to the same physical assumptions and modelled to produce the same amount of milksolids (Table 1). Surplus pasture was managed to be cut for silage. Pasture growth and animal demand were matched, and feed deficit was filled by purchasing more feed. All purchased feed was pasture silage. The average body condition score was 4.8 before calving and 4.1 at drying off in May. Farm scenarios were ranked and compared by profit expressed as earnings before tax.

Operating costs and expenditures

Farm profitability (measured as farm operating profit) was calculated as: total revenue (from net milk sales, livestock sales and net capital value changes) - total farm working expenses, where total farm working expenses = sum of (labour/wages expenses, livestock expenses, feed expenses, cost incurred for grazing livestock replacements off farm, expenses such as fertilizer, nitrogen, irrigation, weed and pest control, vehicle expenses, overhead expenses including administration, insurance, rates and depreciation). Operating costs and dairy farm expenditure were sourced from Farmax for dairying in the Canterbury region in 2013-2014. The milk price was set at NZ $6.00 per kg MS, in accordance with the long-term average milk sale price across the main NZ dairy companies (NZ$6.11 MS; LIC 2015).

Results and discussion

Metabolisable energy

The monthly ME in the diet data are presented in Table 2. The average ME for all farm scenarios was 12.9 MJ ME/kg DM during spring (September to November), 11.8 MJ ME/kg DM during summer (December to February), 12.1 MJ ME/kg DM during autumn (March to May) and 12.8 MJ ME/kg DM during winter (June to August). These values are comparable with those of Nobilly et al. (2013) who reported ME of diverse pasture range from 11.5 to 12.9 MJ ME/kg DM depending on the season, and within the range of 11.5 to 13.0 MJ ME/kg DM suggested to meet requirements of grazing dairy cows for milk production (Waghorn et al. 2007).

Figure 1 Monthly average pasture growth rates (kg DM/ha/day) for two pasture mixtures and three grazing management regimes. DP + CG, conventional grazing of diverse pasture; DP + AL, autumn lenient grazing of diverse pasture; DP + SL spring lenient grazing of diverse pasture; IDP + CG, conventional grazing of diverse pasture with Italian ryegrass; IDP + AL, autumn lenient grazing of diverse pasture with Italian ryegrass; IDP + SL, spring lenient grazing of diverse pasture with Italian ryegrass. Bars indicated standard error of the means.

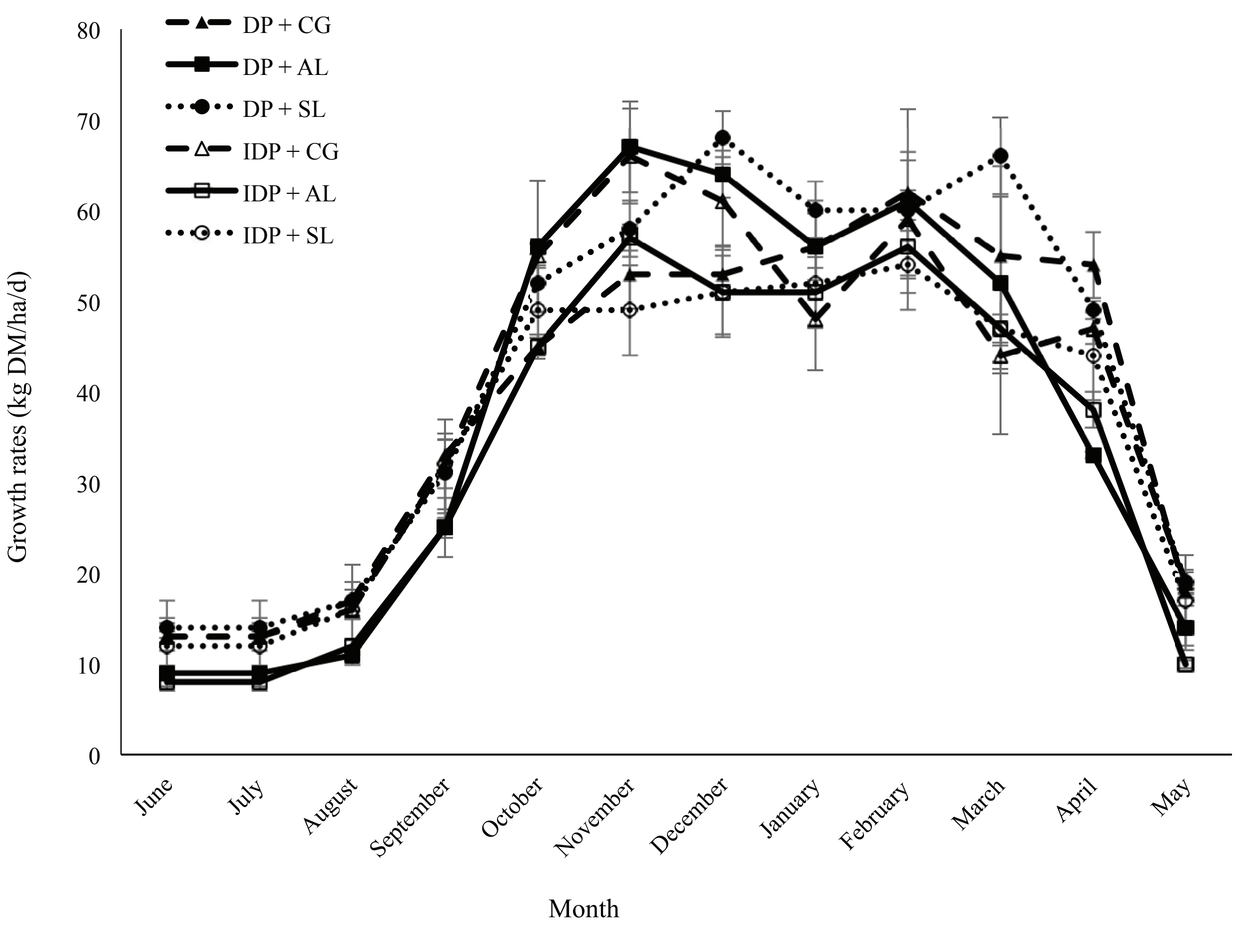

Table 2 Effects of grazing management and diverse pasture mixture on monthly pasture metabolisable energy (MJ ME/kg DM)

	Farm Scenarios[1]					
Month	DP + CG	DP + AL	DP + SL	IDP + CG	IDP + AL	IDP + SL
January	11.6 ± 0.64	11.1 ± 0.16	12.2 ± 0.05	11.1 ± 0.24	11.9 ± 0.66	12.3 ± 0.41
February	10.7 ± 0.31	11.6 ± 0.26	11.6 ± 0.27	11.4 ± 0.36	12.1 ± 0.40	12.2 ± 0.25
March	11.2 ± 0.25	11.4 ± 0.42	11.1 ± 0.54	11.1 ± 0.31	12.4 ± 0.13	12.0 ± 0.23
April	11.8 ± 0.51	12.3 ± 0.32	11.0 ± 0.18	12.9 ± 0.35	12.7 ± 0.28	10.9 ± 0.21
May	12.6 ± 0.40	12.4 ± 0.42	12.7 ± 0.02	12.9 ± 0.19	12.8 ± 0.15	12.8 ± 0.03
June	12.7 ± 0.34	12.5 ± 0.40	12.8 ± 0.02	13.0 ± 0.07	12.9 ± 0.13	12.7 ± 0.08
July	12.7 ± 0.34	12.5 ± 0.40	12.8 ± 0.02	13.0 ± 0.07	12.9 ± 0.13	12.7 ± 0.08
August	12.9 ± 0.30	12.6 ± 0.38	13.0 ± 0.05	13.2 ± 0.05	13.0 ± 0.11	12.7 ± 0.17
September	12.9 ± 0.16	12.8 ± 0.34	13.2 ± 0.11	12.6 ± 0.20	13.2 ± 0.07	12.4 ± 0.24
October	12.7 ± 0.06	12.8 ± 0.34	12.7 ± 0.31	12.6 ± 0.20	13.2 ± 0.07	12.4 ± 0.24
November	13.8 ± 0.59	12.6 ± 0.25	13.1 ± 0.34	13.2 ± 0.03	13.3 ± 0.05	13.1 ± 0.12
December	12.2 ± 0.45	11.9 ± 0.19	11.7 ± 0.20	12.3 ± 0.41	12.3 ± 0.58	12.5 ± 0.23

[1]DP + CG, conventional grazing of diverse pasture; DP + AL, autumn lenient grazing of diverse pasture; DP + SL spring lenient grazing of diverse pasture; IDP + CG, conventional grazing of diverse pasture with Italian ryegrass; IDP + AL, autumn lenient grazing of diverse pasture with Italian ryegrass; IDP + SL, spring lenient grazing of diverse pasture with Italian ryegrass. Values are treatment means within the month ± standard error of the means.

Model outputs and financial performance

The Farmax model output on herbage DM production, supplement usage and production, and cost and operating profit are presented in Table 3.

Profit was numerically higher for DP+SL (NZ$2658/ha) compared with other scenarios (average NZ$2261/ha). The greater profit was driven by greater annual DM production (15.0 vs average 13.3 t DM/ha) and hence, less purchased feed required to meet animal requirement (NZ$0/ha vs average NZ$404/ha) for diverse pasture managed by spring lenient grazing compared with other scenarios, respectively. In addition, the lenient grazing of diverse pasture in spring was the only scenario that resulted in a surplus feed and therefore a positive adjustment in feed supply (NZ$3145/year).

The amount of supplement offered varied among the farm scenarios, ranging from 0.4 t DM/ha to 3.1 t DM/ha. Pastures managed by lenient grazing in autumn resulted in the greatest amount of supplement fed (average 2.9 t DM/ha) compared with pastures managed conventionally or leniently in spring (average 1.9 and 1.2 t DM/ha, respectively). Pastures managed by lenient grazing in autumn resulted in the lowest DM production compared with other farm scenarios (12.7 vs average 14.0 t DM/ha, respectively). This low pasture production could be attributed to the accumulation of dead material in the base sward during winter due to lenient grazing in autumn. The high amount of dead material could have shaded the base of the sward, reducing the light intensity and, hence, tiller development (Hunt & Field 1978). In the diverse pasture mixture, average annual herbage yield increased by 1.0 t DM/ha when leniently grazed in spring compared with conventional grazing. The greater herbage yield from the lenient grazing in spring scenario could be attributed to two possible reasons. First, lenient grazing in spring increased daughter tillers of perennial ryegrass from November to January. By allowing the reproductive parent tiller of ryegrass to develop to anthesis (i.e., early flower stage) before removal by grazing or mowing, daughter tiller survival is aided (Matthew et al. 1989), resulting in greater herbage mass (Da Silva et al. 1994). Da Silva et al. (1994) reported a 20% greater herbage mass in subsequent grazing in spring and summer using a spring lenient grazing. This is possibly due to better nutrition of daughter tillers owing to the strongly growing parent tiller and reabsorption of nutrients from the decapitated flowering stem base. Second, lenient grazing was better suited for optimal legume and herb proportions. The spring lenient grazing management in this study resulted in 32% herbs (plantain and chicory) and 17% legumes (red clover and white clover) of the botanical composition. These values are greater than the 27% herbs and 13% legumes observed in botanical composition of diverse pasture grazed conventionally. The concern with lenient grazing is pasture quality may decline in the subsequent grazing rotation and ultimately affect milk production. One suggested approach to alleviate the decline in pasture quality is mowing before grazing (Bryant 1982; Kolver et al. 1999). However, previous work from this group (Cun et al. 2017a), showed no benefit to milk production from mowing diverse pastures of high herbage mass once before grazing in spring. In addition, it has been demonstrated (Cun et al. 2017b) that diverse pasture mixtures can be leniently grazed and maintained at a high herbage mass in spring without affecting milk production in the subsequent grazing rotation.

Extra herbage growth, and subsequent herbage production, was expected during winter/early when Italian ryegrass was included in the diverse pasture mixture. This is because Italian ryegrass showed higher growth rates than perennial ryegrass, legumes and herbs during winter (Charlton & Stewart 1999). However, in present study, the inclusion of Italian ryegrass in the diverse mix sward did not influence herbage production (Figure 1). Similarly, Stevens and Hickey (2000) confirmed that the combination of two temperate grasses (perennial ryegrass, cocksfoot or tall fescue) sown together did not improve New Zealand pasture yield. The competition for resources from similar species may have caused the lower pasture yield. This lower herbage production for diverse mixture with Italian ryegrass resulted in a greater cost per kg MS compared to diverse mixture without Italian ryegrass (NZ$4.40 vs NZ$4.32, respectively). Further, lenient grazing for the diverse mixture + Italian ryegrass resulted in further reduction in herbage DM production compared to the conventional grazing (12.6 vs 13.9 t DM/ha, respectively) and, thereby, larger feed deficits in summer and autumn. This required a large amount of supplementary feed to maintain herbage mass above 2000 kg DM/ha compared to conventional management of diverse pasture + Italian ryegrass. When diverse pasture + Italian ryegrass was managed by conventional grazing, no additional feed was purchased. This implies that when diverse pasture + Italian ryegrass mixture is considered, conventional grazing rather than spring or autumn lenient grazing would potentially result in greater operating profit (NZ$2400, NZ$2337 and NZ$2067/ha, respectively).

Conclusion

When diverse pasture is considered, spring lenient grazing is a potential management option for irrigated Canterbury dairy farm systems to increase herbage yield. This resulted in a reduction in purchased feed costs, and, thereby, greater farm profit.

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Table 3 Farmax model output from whole-farm modelling using an average North Canterbury farm system with three grazing managements and two pasture mixtures on an irrigated 229 ha dairy farm. Operating profit is based on a milk price of NZ$6.00/kg milksolids, 3.4 cows/ha stocking rate and milksolids production of 416 kg MS/cow/yr.

	Farm Scenarios[1]					
Variable	DP + CG	DP + AL	DP + SL	IDP + CG	IDP + AL	IDP + SL
Annual herbage yield (t DM/ha)	14.0	13.4	15.0	13.9	12.0	13.2
Supplements fed (t DM/ha)	2.1	2.6	0.4	1.7	3.1	1.9
Cost of purchased feeds (NZ$/ha)	340	484	0	262	597	335
Pasture conserved (NZ$21/ha)	4840	0	4840	4840	0	0
Surplus feeds (NZ$40/ha)	0	0	3145	0	0	0
Operating profit (NZ$/ha)	2309	2194	2658	2400	2067	2337

[1] DP + CG, conventional grazing of diverse pasture; DP + AL, autumn lenient grazing of diverse pasture; DP + SL spring lenient grazing of diverse pasture; IDP + CG, conventional grazing of diverse pasture with Italian ryegrass; IDP + AL, autumn lenient grazing of diverse pasture with Italian ryegrass; IDP + SL, spring lenient grazing of diverse pasture with Italian ryegrass. Values are treatment means within the month ± standard error of the means.

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